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Abstract

# THORIUM UTILIZATION SYSTEMS

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The use of thorium in nuclear power reactors is of interest because the uranium-233 bred into the thorium has a better neutron yield in thermal power reactors than either uranium-235 or plutonium-239. Fuel systems based on thorium and recycled uranium-233 might therefore be expected to have higher conversion ratios and longer fuel lifetimes than natural uranium or slightly enriched uranium fuels. These attributes, in turn, might possibly result in lower power costs. In certain reactor types moreover, it may be possible not only to achieve low power costs but also to breed uranium-233 sufficiently to achieve a self-sustaining recycle system whereby no supplementary input of fissile material would be required.

Because of these possible advantages, thorium-fueled reactors might constitute an important segment of future nuclear-power systems; however, the integration of such reactors into any existing nuclear industry requires that they be economically competitive with reactors based on the use of natural uranium or slightly enriched uranium. It is important, therefore, that thorium-utilization systems have the combined capability of being economically competitive for the short term and of making efficient use of thorium for the long term. These two criteria form the basis for the evaluation and selection of reactor types that might be most promising for developing a nuclear industry involving the use of thorium. This paper summarizes the design characteristics of various thorium converter reactors and reviews the results of recent studies and evaluations of their economic potential. Thermal converter types considered include light-water seed/blanket, spectral-shift controlled, heavy-water moderated, high-temperature gas cooled, and graphite-moderated molten

salt. Data are given to indicate the nuclear performance and associated potential of each concept for achieving competitive power costs during the period 1970-1980 and at the same time conserving supplies of low-cost uranium. The potential of each system for achieving self-sustaining fuel recycle and utilization of high-cost ores is also indicated. Factors that influence power costs in these high-neutron-economy converters such as, conversion ratio, fuel specific power, recycle fuel composition, fuel processing rates, method of processing, unit fuel cycle costs and economic ground rules are also discussed.

To achieve the long-term goal of developing an economic nuclear industry based on the use of high-cost ores may require thorium breeders with even better nuclear performance and lower unit fuel processing costs than the high-neutron-economy converters described above. Very little development work aimed specifically at such thermal breeders is at present under way in the United States; however, a number of concepts have been designed and evaluated for the purpose of establishing the incentives for initiating development programs. Concepts considered include aqueous homogeneous slurry breeder, two-region molten-salt breeder, liquid-bismuth breeder, gas-cooled graphite breeder, and gas-cooled heavy-water breeder. Data on fuel cycle costs as a function of breeding ratio, fuel yield (or inventory doubling time), and fuel specific power are presented to indicate the breeding potential of these concepts and their outlook for achieving economic power from high-cost nuclear source materials.